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Embedded Switches: Is it Time for Automation Component Suppliers to Get on the Bandwagon?

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Introduction

Embedding intelligence is maturing. Embedded computers in automobiles, home appliances, smart phones, TV receivers, and video recorders revolutionized industries – and, indeed, life, around the globe. Trade shows capitalizing on the trend have become institutions: the Embedded Systems Conference in Silicon Valley is 24 years old and Embedded World in Nuremberg, Germany, is celebrating its 10th year.

Today, 98% of Ethernet switches are still stand-alone units. This physical separation clearly differentiates between communication tasks and application processes; nonetheless, the increasing requirements to reduce cost and save space are swinging the momentum towards embedded switching in automation components for industrial machines.
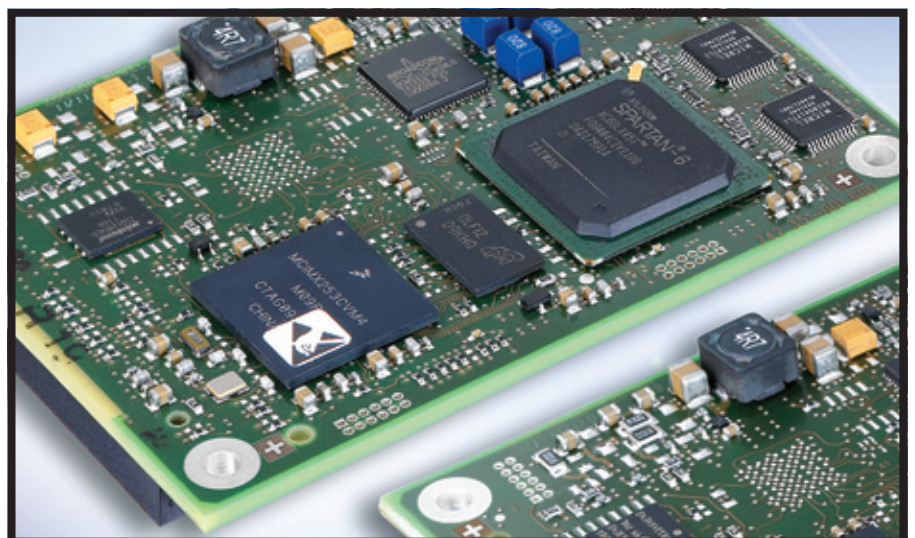
The first managed Ethernet switches that were designed as board-level systems were introduced less than two years ago. These switches are designed to be integrated on the main boards of automation components. Just as embedded intelligence has become ubiquitous in the machines we use in daily life, embedded Ethernet is the way of the future for industrial applications. Machine manufacturers will be able to develop systems with smaller footprints and enhanced capability because the machines, being part of the system, will be able to "speak" Ethernet-based automation protocols such as ProfiNet, Ethernet/IP and EtherCAT.

Integrating Ethernet technology from the ground up into an automation component for a machine is no easy task. Embedded Ethernet boards fill a much-needed gap between large stand-alone Ethernet switches and switching chips, which still required significant design effort to embed into an automation component like an intelligent tool. These new embedded Ethernet switches provide almost "drop-in" Ethernet functionality and dramatically decrease the time it takes for an automation component manufacturer to migrate an in-production design into a state-of-the-art Ethernet-enabled product. Component designers are no longer required to master a different technology (Ethernet), and can instead focus on their area of expertise.

Not only do component manufacturers win from a time-to-market standpoint, but embedded Ethernet switching is considered a benefit to machine manufacturers and their customers because it reduces the footprint of a solution in facilities where space is at a premium, and it saves in cost and complexity. Lower design risks and increased perceived value to the customer make a powerful combination.

Be certain.
Belden.

Convergence of Control and Communications Technology

The emergence of embedded Ethernet switches in industrial equipment is an example of the increasing convergence of control and communications. As the technology evolves to reduce switch functionality from a stand-alone system to a board within a machine, everyone wins. The ARC Advisory Group, a leading research and advisory firm for industry and infrastructure, published a paper in 2011 entitled Embedded Ethernet Switching Expands beyond Motion Control that concluded: "Ethernet switches embedded in end devices such as I/O, HMI, and drives can lower installed network costs, simplify network design, improve performance, and enable more flexible topologies."

Decreasing the Ethernet Footprint Enables Component Designers to Add Increased Functionality in Equipment

Semiconductor technology has allowed for increasing reduction in the foot-print of Ethernet "boxes". Because chips have gotten both smaller and more intelligent, it is possible to develop embedded Ethernet switch functionality that can be integrated into components for industrial machines, saving external wiring and connector costs, as well as space. The first embedded Ethernet applications were in sensor/actuator control, and have expanded into embedded Ethernet switches for logic, discrete machine control, data acquisition, and even real-time motion control, as Ethernet approaches true real-time performance.

While miniaturization and time will likely continue to reduce the cost of embedding a switch in an automation component, today embedded options are most typically designed into automation components that are priced at $1000 or greater.
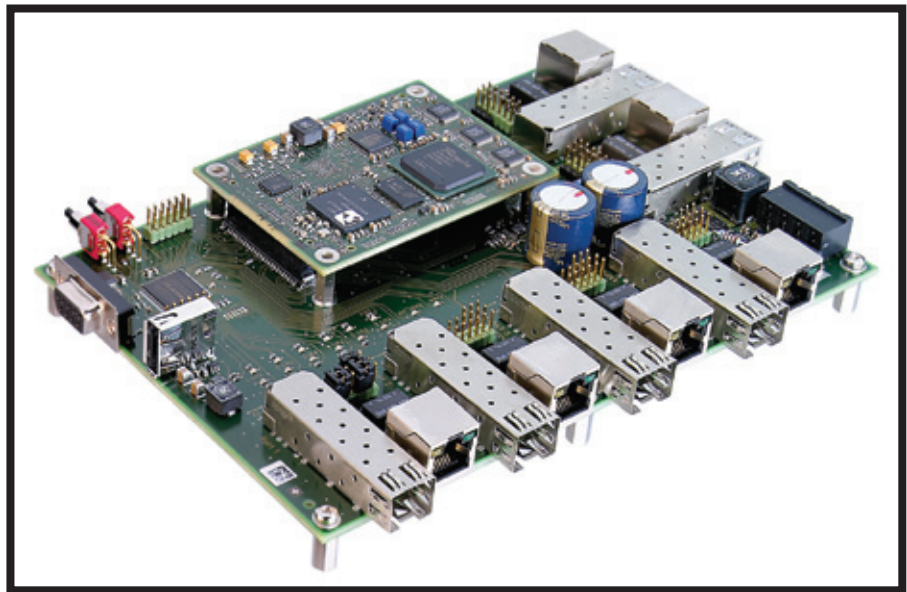

Fig. 1 Embedded Ethernet switch (small board, top) assembled with a main board of an automation component

Component Manufacturer's Benefits

The benefits of embedded Ethernet boards are compelling on the component manufacturer side – shorter time to market, reduced risk in implementing the design, and future proofing. From the designer's point of view, embedded Ethernet offers a "shortcut" to getting new products out. Embedded Ethernet switches provide pre-designed and pre-tested network functionality, which reduces the time and effort it takes to integrate Ethernet switches into the automation component for machinery.

Because the manufacturer of the embedded Ethernet switch takes on the responsibility for being up-to-date on Ethernet technology and delivering functioning product, the designers are free to concentrate on what they know best – the functionality and requirements of their components. In addition, embedded Ethernet boards have the capability for field upgrades to keep software current with the latest management and security technology.

Machine Builder and Customer Benefits of Embedded Ethernet Technology

Automation components with Ethernet switches integrated provide added value in the eyes of not only component designers but also machine builders and end customers. An industrial machine with embedded Ethernet not only saves the customer valuable real estate on the manufacturing floor, but also reduces costs by eliminating the need for a stand-alone Ethernet switch. As a reference, the price of a managed embedded Ethernet switch is 20 to 25% of the cost of a stand-alone switch with similar capabilities, thus the overall cost to the customer will be less. Not only is one box eliminated, but also cabling costs and power connections are reduced. In addition, the customer's service and support arrangements will be improved because a single supplier is responsible for connectivity and control functionality.

The History of Industrial Networking

Figure 2 shows some of the milestones in the evolution of Ethernet switches from the original commercial system optimized for use in an Enterprise IT environment to a robust and deterministic technology suitable for industrial applications.

Since its introduction more than 20 years ago, Ethernet technology has been refined and revised to extend its reach from protected office environments to industrial applications that require determinism and fault-tolerance. Supported Ethernet topologies evolved from the simple daisy chain to hub-and-spoke, and then to ring and mesh topologies. The latter two (ring and mesh) support redundancy schemes, which are a prerequisite for Ethernet use in many mission-critical industrial applications.

The advent of network management software allowed Ethernet to become effective for complex industrial applications. Redundancy is important in industrial automation applications where interruption is expensive or dangerous. Protocols such as MRP (Media Redundancy Protocol) enable vendors to build industrial Ethernet systems that are both deterministic and highly redundant, and RSTP (Rapid Spanning Tree Protocol) dramatically reduces the speed at which networks can self-heal after a fault. Some applications, however, cannot tolerate millisecond, or even microsecond delays due to a fault in the network. One clear example of this is when Ethernet is used to transmit samples of current and voltage, which requires zero failover for correct actions in substations. Technologies including PRP (Parallel Redundancy Protocol) and HSR (High Speed Redundancy) address these requirements.
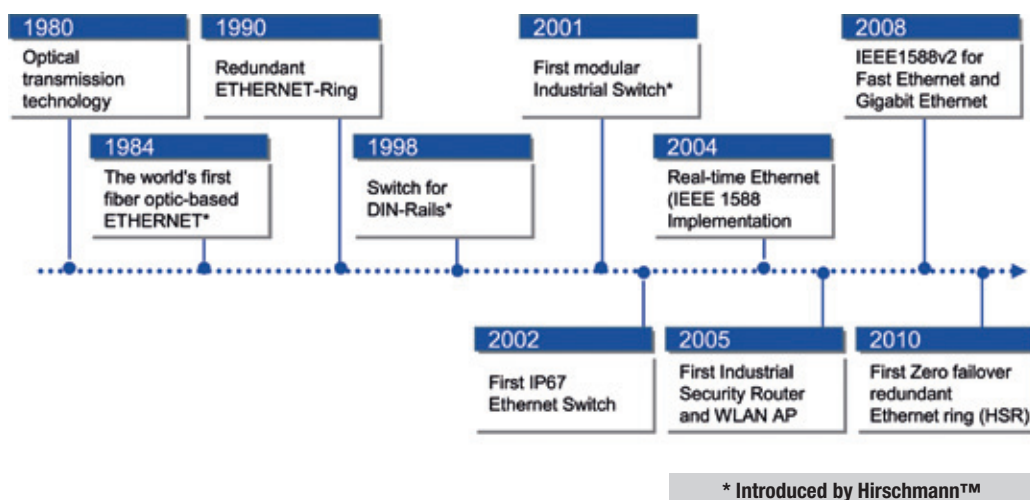

Fig. 2 Evolution of Industrial Ethernet – Hirschmann has taken a leadership role in developing many of the industrial standards that have moved Ethernet effective in this market.

Design Considerations

Managed embedded Ethernet boards make a rich portfolio of network functions available within industrial machines themselves to provide the best level of support for industrial machines and today's extended networks. Today, it is possible for data to be collected directly from the machine and made available to a central network management system. Network management tools, such as Hirschmann's HiVision firmware, enable control engineers in a central location to monitor and manage standard Ethernet devices, including updating software and changing configurations remotely. It is possible to manage a network from a device physically linked to the network or via the web, for greater flexibility.

In addition, network management tools provide alarm and event monitoring and notification, and a database that logs error information for later evaluation. This kind of functionality is invaluable for supporting systems that are required, by their nature, to be high availability for critical manufacturing tasks.

Network management tools enable important elements of an industrial network environment, including redundancy, port configurability, real-time operation, and remote software updates. Other important elements in choosing embedded Ethernet include industrial hardening and technical support.

Redundancy

The new high-availability and redundancy standards, PRP (Parallel Redundancy Protocol) and HSR (High-availability Seamless Redundancy) offer zero failover fault protection and extend the benefits of Ethernet to even the most sensitive

industrial automation projects. The adoption of these protocols removes the last hurdle to Ethernet's ascendancy as THE networking infrastructure of choice for industrial environments. (See Sidebar)

Real-time Operation

IEEE 1588v2 real-time support is especially important for distributed automation systems. Precision Time Protocol (PTP), described in IEEE 1588, allows the synchronization of distributed clocks with an accuracy of less than 1 microsecond. Motion control, robotics, and test and measurement applications are examples of applications where precision timing is mandatory.

Remote Software Upgrades

The ability to update the embedded Ethernet board via software is another capability that

makes it attractive. Component manufacturers an design in these embedded Ethernet boards and upload new software as required remotely; no factory recalls or expensive service calls are required.

Industrial Hardening

Embedded Ethernet in industrial components should be hardened to meet industrial standards. Although being embedded in a machine affords some measure of protection to Ethernet components, the machines can still be located in hostile environments. Embedded Ethernet boards that are designed with extended temperature chips, and with careful attention to eliminating hot spots which could cause failures in the field, are necessary to ensure high reliability. In addition, optional conformal coating can protect against moisture and corrosive chemicals.
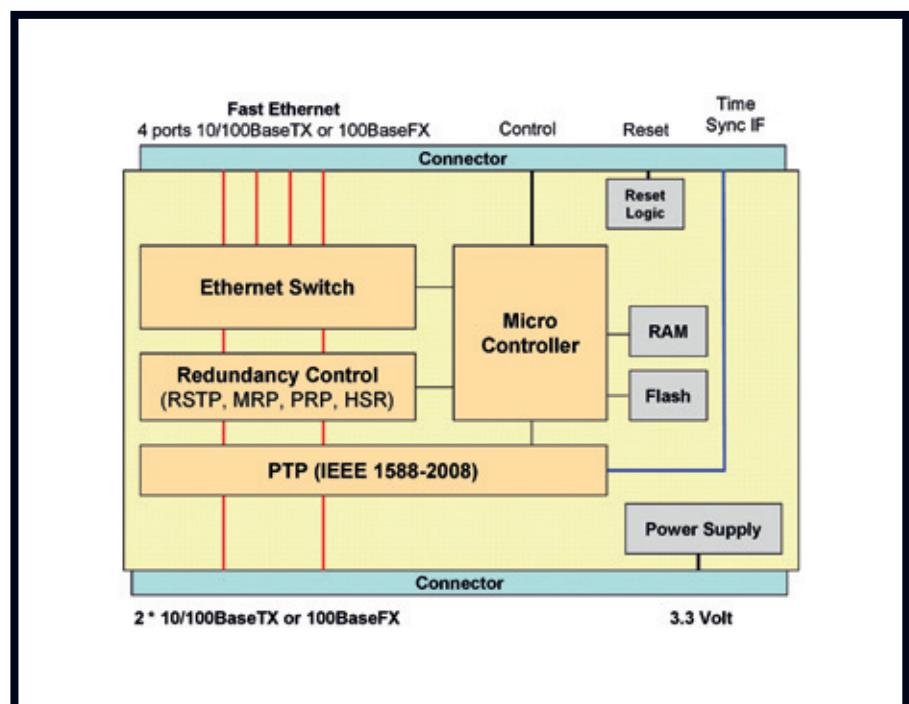

Fig. 3 Block diagram of embedded Ethernet system

IEC 62439 High-Reliability Networks for Mission Critical Applications

Unlike commercial Ethernet networks, where the integrity of the data is key and some downtime can be tolerated, industrial Ethernet networks must be highly reliable and the cost of failure quickly escalates to unacceptable levels. Consider a network failure in a food processing operation where batches may be spoiled if there is delay, or power substations where failure can result in blackouts that can precipitate life-threatening situations, or intelligent traffic systems monitoring traffic events and managing heavy traffic flow that suddenly go dark.

The sidebar "The History of Industrial Networking" describes the progress made in industrial network redundancy strategies and fault recovery protocols over the years, however, most of those have been dependent on network reconfiguration, which requires a brief interruption in communications during the switchover process. Although delay time has been driven to the microsecond range, it is still a delay.

IEC 62439 provides standards for high-reliability networks for mission critical applications and describes PRP (Parallel Redundancy Protocol) and HSR (High-availability Seamless Redundancy). PRP and HSR guarantee behavior under failure conditions and increase network reliability. To be exact, they provide network redundancy and seamless failover from a single point of failure by duplicating packets in a network and sending them to their destination on separate paths. If one of the set of data packets is not delivered due to network failure, the other will still arrive. When the system is healthy, the duplicate packet is simply discarded.

PRP fulfills the hard real-time requirements of demanding applications such as substation automation by specifying parallel operation of two LANs, and provides seamless switchover in case of failure of links or switches. HSR introduces the concept of Double Attached Nodes (DANs), which have a three-port switch. The internal port feeds the same data to two external ports that transmit frames in opposite directions around a ring. Redundancy Boxes (RedBoxes) allow non-HSR-capable devices to be connected to HSR networks.

Technical Support

Perhaps the most important feature to consider when specifying embedded Ethernet switches is the human support behind it. Embedding Ethernet in a machine provides cost savings, reliability and enhanced functionality.

Understanding the capabilities of the embedded Ethernet board and how to use it can best be facilitated by having Ethernet vendor-provided support available to work with the component manufacturer's engineering and R&D depart-ments. Vendor support in areas such as network design, trouble shooting, network configuration, firmware upgrades and redundancy imple-mentation can make a huge difference in time-to-market of the first design and for troubleshooting over the life of the product.

It is important to look for a vendor with in-depth experience in industrial network designs and multiple levels of support that allow OEMs to access the level they need from online chats to on-site technical consultation.
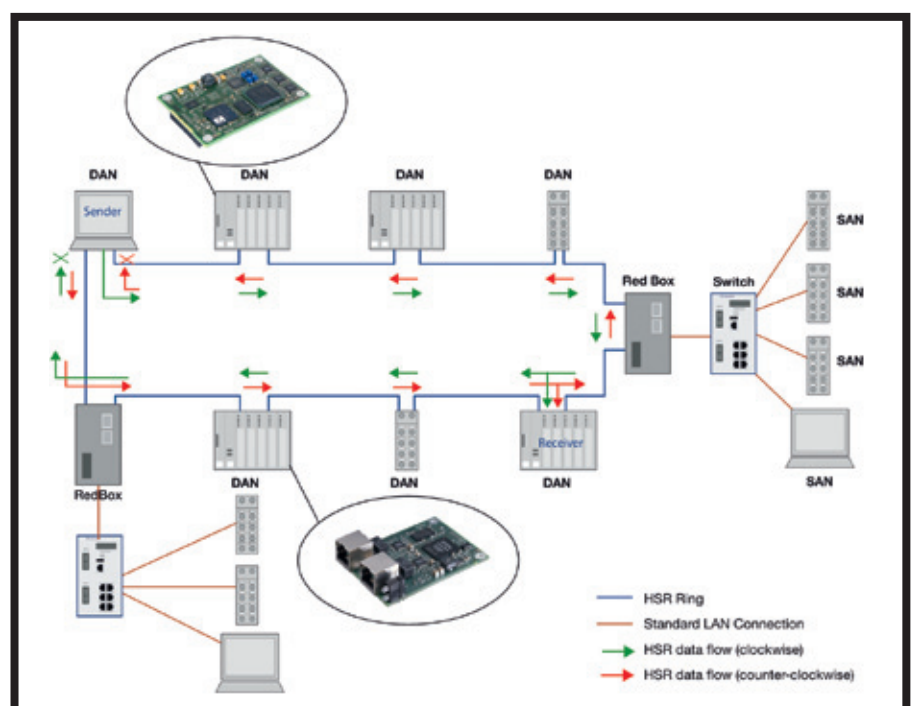

Fig. 4 A mix of stand-alone and embedded switches provides optimum configuration in an industrial environment.

Application Example

A good example of a market that benefits from embedded switches is food processing. Food processing equipment requires frequent sanitization with high-pressure liquids and strong chemicals, and needs to withstand temperature extremes – from high heat in ovens to refrigeration and freezing conditions.

Reducing the number of pieces of equipment will limit possible points of failure, as well as save real estate. In other applications, such as materials handling and power, the reduction in space requirements and the savings from integrating multiple functions into the same box are powerful arguments for embedding switches.

Although the functionality of a standalone switch is identical to that of an embedded switch, there are differences in the form factor and interfaces. Figure 4 shows an application that mixes high-port-count stand-alone managed switches and embedded Ethernet systems.

Embedded Ethernet switches are most valuable for extended automation systems and provide powerful managed network functionality in distributed systems with multiple external devices such as substation automation protection relays, remote terminal units (RTUs), and communication gateways.

In Figure 4, (previous page) Ethernet switches and embedded Ethernet boards are integrated in a highly reliable industrial Ethernet network using HSR. Duplicate information packets are circulating in a redundant ring structure. One set of packets circulates counterclockwise (red arrows) while the other set runs clockwise (green arrows). If a packet gets lost due to a cable break or other transmission failure, the second packet will reach its destination without any delay. Dual attached nodes (DAN) and redundancy boxes (Red Box) ensure seamless data flow throughout the network.

Summary

In the last 20 years, Ethernet has made significant contributions to the efficiency and reliability of industrial operations. As Ethernet becomes the standard for industrial automation, its integration into the machines themselves becomes more desirable. Recently introduced protocols that provide zero failover are removing the last barriers to Ethernet in industrial applications.

Embedded managed Ethernet boards provide the mechanism for rapid deployment of Ethernet-enabled devices. Ethernet boards are virtually "drop-in" technology. Automation component manufacturers concentrate on their areas of expertise and use pre-configured, pre-tested embedded Ethernet systems to bring Ethernet-enabled machines to market rapidly and provide added value for end users.

By carefully selecting Ethernet boards that have the functionality required today and the capability for upgrades in the future, OEMs can get ahead of the curve, providing Ethernet capability and extra value to their customers with little additional investment.

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